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International application number: PCT/US05/004412

International filing date: 14 February 2005 (14.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/544,582
Filing date: 13 February 2004 (13.02.2004)

Date of receipt at the International Bureau: 14 March 2005 (14.03.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

1292546

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APPLICATION NUMBER: ***60/544,582***
FILING DATE: ***February 13, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/04412***

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

MAIL STOP PROVISIONAL APPLICATION
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Transmitted herewith for filing is the Provisional Patent Application of:

Given Name (first and middle [if any])	**Family Name or Surname**	**Residence** (City and either State or Foreign Country)
Hing L.	Chiu	7615 Lindsay Lane Solon, Ohio 44139 US

Title of the invention:

LOW COST GEAR FUEL PUMP FOR AIRCRAFT APPLICATIONS

Enclosed application parts (*check all that apply)*

- ☒ 7 Pages of Specification
- ☒ 5 Sheets of Drawings (Figures 1-5)
- ☐ ____ Page of Abstract
- ☐ Application Data Sheet
- ☐ CD(s)
- ☒ Other (specify) Attachment A (16 pages)

Method of Payment of Filing Fees for this Provisional Application for Patent:

- ☐ Applicant claims *small entity* status. See 37 CFR § 1.27.
- ☒ A check is enclosed to cover the filing fees.
- ☒ The Commissioner is hereby authorized to charge any deficiencies in the filing fees or credit any overpayment to Deposit Account No. 06-0308.

FILING FEE AMOUNT: **$160.00**

☐ The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government:

- ☒ No
- ☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Please direct all correspondence to:

Mark S. Svat, Esq.
FAY, SHARPE, FAGAN, MINNICH & McKEE, LLP
1100 Superior Avenue
Seventh Floor
Cleveland, OH 44114-2518

February 13, 2004
Date

Mark S. Svat
Reg. No. 34,261
FAY, SHARPE, FAGAN,
MINNICH & McKEE, LLP
1100 Superior Avenue
Seventh Floor
Cleveland, OH 44114-2518
216/861-5582

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I hereby certify that this *PROVISIONAL APPLICATION FOR PATENT COVER SHEET* and accompanying papers are being deposited with the United States Postal Service "Express Mail Post Office To Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to the MAIL STOP PROVISIONAL APPLICATION, Commissioner For Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Karen M. Forsyth

Provisional Application for:

LOW COST GEAR FUEL PUMP FOR AIRCRAFT APPLICATIONS

BACKGROUND

[0001] Powdered metal gears and bearings have been developed and successfully used by automotive and gardening equipment manufacturing. Their popularity has been gaining momentum lately as techniques of powdered metal technology improves and evolves. Powdered metal parts have not currently been considered for use in aircraft fuel pumps as gears, bearings or other components.

[0002] A typical aircraft gear fuel pump is a fixed displacement pumping device. It receives fuel from the fuel tank at a low pressure, pressurizes and delivers the fuel at a much higher pressure to the fuel nozzle via a fuel control for engine combustion. It functions similarly to the heart of the human body. A conventional aircraft fuel pump generally consists of a matched pair of high precision spur gears, running on four separated bearings, driven by a splined shaft. All components are packaged in an aluminum housing. It sometimes requires an impeller to boost the inlet pressure, and a pressure relief valve for safety check.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIGURE 1 illustrates components made according to the present application, as well as components designed in accordance with conventional manufacturing processes;

[0004] FIGURE 2 illustrates top views of powdered metal bearings according to the present application;

[0005] FIGURE 3 illustrates a bottom view of powdered metal bearings according to the present application;

[0006] FIGURE 4 depicts side views of powdered metal bearings according to the present application; and

[0007] FIGURE 5 illustrates a gear designed in accordance with the present application.

DETAILED DESCRIPTION

[0008] The formation of powder metal gears and bearings have been known in various arts such as automotive and gardening equipment. However, due to the high stresses and need for superior performance, use of components made by powdered metal technology has not been considered in the area of fuel pumps used in aircraft. Particularly, powdered metal technology has in the past been known to become somewhat unreliable when operating under a high degree of stress. However, recent advancements have resulted in improvement in powder metallurgy whereby the present inventor has been able to form gears, pressurized bearings, fixed bearings as well as other fuel pump components which, when tested, produce results in areas at least as good as those obtainable by conventional design approaches.

[0009] Using powder metal technology the inventor was able to manufacture components for a fuel pump for aircraft applications which result in a much-improved manufacturing cost structure for fuel pump fabrication and assembly. This is true since gears, bearings and drive shafts constitute the majority of the fuel pump components.

[0010] The aircraft fuel pump components made using powder metal technology may be made using existing powdered metal technology. A description of this technology is provided, for example in Attachment A, entitled *Conventional Powdered Metal Components* hereby incorporated in its entirety as part of this application. It is to be appreciated, however, that the manufacturing technology processes for manufacturing these components is not limited simply to that described in this document, but may incorporate any other powder metal manufacturing processes.

[0011] Benefits over the existing conventional design approach as compared to the low cost powdered metal design approach of the present application are set forth, in one example, in the following Table:

Featur	Conventional Design Approach	Low Cost P/M Design Approach
G ar	Gear and journal one piece fabrication	Gear blank and journal formed separately

Feature	Conventional Design Approach	Low Cost P/M Design Approach
Gear Teeth	Rough machined individually and final ground. Part inspection required. High Cost (about $800-$2500 per set).	Precision Carbide Tooling fabricated once, net shape formed, millions can be pressed without changing the tooling. Random sampling is required. High initial tooling cost but very low formed piece part cost (approximately $25-$30 each).
Gear Journal	Cut from a circular bar stock together with the gear. Both sides of journal size to be matched precisely. Integrated with gear, one piece construction.	Separated center-less ground. One journal, no matching problem. Key way is needed to drive the gear blank. Retaining rings to position the gear blank (approximately $25-$30 each).
Gear Width Matching	Matching to about .0002 inch, large pool of inventory is required for matching. Parallel to within about .0002 inch.	Dozen can be ground to the same height at once, no matching is required. Two sides will be automatically parallel.
Thrust Face Finish	Special super finishing operation.	Not required, as ground.
Deburring	Required, time consuming.	Tumble finish, a very simple operation.
Drive	Splined shaft, costly.	Hex Drive, low cost.
Total Cost	Very high	approximately 30% of conventional cost
Pressurized Bearing	Two separated parts	One piece construction
Drive Bearing	Fabricated individually. Final lapping at pump assembly. High precision machining required.	Designed for Powdered Metal application. One single piece. Net shape bronze powdered metal. Minimum machining required. One time initial tooling cost, very low per piece formed part cost (approximately $3.00-$5.00 each).
Driven Bearing	Fabricated individually, different from drive bearing. Final lapping at pump assembly. Relatively high cost.	
Loading Spring	Generally 12 for pressurized bearings	About one
Fixed Bearing	Two fixed and two pressurized	One piece construction
Drive	Fabricated individually. Final lapping at pump assembly	One single piece. Net shape bronze powdered metal. Minimum machining is required. No matching is needed. One time initial tooling cost, very low per piece formed part cost. (approximately $2.00-$4.00
Driven	Fabricated individually, different from drive bearing. Matching in height is required. Final lapping at pump assembly. Relatively high cost.	

Feature	Conventional Design Approach	Low Cost P/M Design Approach
		each).
Total Cost	High	approximately 25% of conventional design.
Drive Shaft	Input and Output splines	Hex shaft cut from standard stock
Total Cost	High	approximately 10% of conventional design.
Total Pum Ass'y Cost	Very High	approximately 20%-30% of the conventional design

[0012] It is to be understood the above percentages and dollar figures are simply estimates and the values may, dependant on the implementation, be different from those cited.

[0013] As previously mentioned, until recently, components manufactured using powdered metal technology had a history fracturing under stress. However, due to improvements the robustness of components made by this technique have reached a quality level enabling the inventor to manufacture components for an airplane fuel pump. Upon testing of the components, it was discovered by the inventor that the components manufactured by the powdered metal technology were sufficiently strong to be used in zero-fault acceptable implementations such as airplane fuel pumps. It is not considered that these components would be possible for such use until the inventor undertook the manufacture and testing to determine the capability of such components and found such components met or exceeded expectations.

[0014] With attention to FIGURE 1, components 10 and 12 are one-piece powdered metal bearings manufactured in accordance with powdered metallurgical techniques and processes. Components 14 and 16 are center-less ground journals (bars) which are used with powdered metal gears 18 and 20 to form a bar-driven gear configuration. Particularly, gears 18 and 20 are located in the center of respective bars 14 and 16. Components 22 and 24 are conventionally manufactured one-piece bar stock driven gears where the bar portion and gear are formed as a single unit. Components 26 and 28 are two-piece pressurized bearings shown in an attached configuration. For example, one bearing 26a is manufactured separate from a second bearing 26b. Thereafter, these bearings are aligned and connected together. The

one-piece bar stock drive gear 22, 24 and the two-piece pressurized bearings 26, 28 are manufactured according to conventional processing techniques not using powdered metal technology.

[0015] It is to be understood that the center-less ground journals (bars) components 14 and 16 are made by conventional metal manufacturing, and it is gears 18 and 20 with which they are respectively associated that are manufactured using powdered metal technology.

[0016] For the journal (bar) 14 and 16, powdered metal is not used, as there will be some sort of hole, and the hole may act to grind up the bearing, so we use a conventional bar stock metal.

[0017] In parallel testing, the inventor reviewed the structural integrity and characteristics of the powdered metal bearings 10 and 12 to the two-piece pressurized bearings 26 and 28. Additional testing was done related to the gearing mechanisms also shown in FIGURE 1. It was determined that the powdered metal components lasted longer than the conventional materials.

[0018] Specifics of the testing are set forth in the following:

- Powdered metal gears were endurance tested on an existing small Alison A250-C30 pump model (3.3 gallon per minute flow). Conventional bar stock bronze bearings and modified pump housing were used. The pump was tested at 4400 rpm and 1000 psig discharge in two distinctive segments of approximately 150 hours. The first 150 hour segment was conducted, utilizing powdered metal gears, ATC P/N SK-32603, machined from powdered metal blanks. Utilization of machined powdered metal gears from blanks is to avoid high tooling cost. The second 150 hour segment was conducted, utilizing conventional designed gears as a baseline in wear and performance comparison..

- The purpose of testing is to verify that Powdered Metal gears can be used as aircraft fuel pump components. After the 150 hour accelerated endurance test, the powdered metal gear teeth sustained less wear than the conventional gear teeth.

- One-piece bronze bearings (one pressurized and one fixed) were fabricated from bar stock. The larger A250-C20 pump model (4.6 gallon per minute flow) was used in a 400 cycle endurance test. Conventional production gears were used to verify the one piece bearing design concept. The test condition was more severe than the pump specification (4200 rpm vs 3754 rpm, and discharge at 1000 psig vs 600 psig). The conventional design bearings have special dry film coating. The one piece bearings have no coating.

- During testing, the pump was in the beginning ran dry for almost two minutes because the pump inlet valve was inadvertently closed. And at one time the pump discharge pressure spiked to 1500

psig before the discharge valve was open. Normally, a conventional design pump would have sustained substantial damage from bearing separation (two separated pressurized and two separated fixed bearings). However, the one-piece bearing design is very tolerant to severe operating conditions. No sign of wear was observed after the 400 cycle accelerated endurance test.

- Special phosphorous bronze with 3% graphite additive net shape powdered metal pressurized bearing were produced. Metallurgical evaluation of bearing segment indicated a very homogeneous grain distribution throughout the entire bearing structure. Surface finish was better than expected. The pressurized bearing configuration is the most complex among all three components to be net shape formed.

- Powdered metal bronze fixed and powdered metal steel gear may be net shape formed after testing of the net shape powdered metal pressurized bearing.

- The reason for testing one component at a time is to verify the design concept, material used, and final low cost net shape powdered metal component fabrication, parameter per parameter and to isolate any component feature deficiency.

[0019] In addition to the uniqueness due to the use of powdered metal technology to make the bearings 10 and 12, additional uniqueness exists in the design itself, as compared to the two-piece pressurized bearings 26 and 28. Therefore, even if manufactured using conventional processes, the one-piece design 10, 12 is distinct from existing pressure bearing designs. Particularly, using the single-unit configuration of 10 and 12, a higher accuracy in alignment is achieved due to the avoidance of connecting two separate pieces. It is possible to precisely align the center points of the openings for the bearings. Whereas when using the two-piece design that is conventional, care must be taken when the two pieces are connected to assure proper alignment.

[0020] A further structural distinction between the single unit pressure bearing design 10, 12 and the two-piece units 26 and 28 of FIGURE 1, is that the single-unit design 10, 12 is a straight line design, *i.e.,* across the top and bottom of the component (*i.e.*, see 30, 32, 34, 36), whereas the two-piece units when connected are shown in a figure-eight design. Having the straight line design permits for a more precise, easier alignment of the single unit systems components 10, 12 into the fuel pump, compared to the figure-eight design of components 26, 28. This also provides greater balance in the

system, as there are equal forces on each side of the opening of components 10, 12, providing a self-alignment feature. Whereas on the figure-eight design, such self-alignment would not be possible, and alignment within the fuel pump becomes a very involved process.

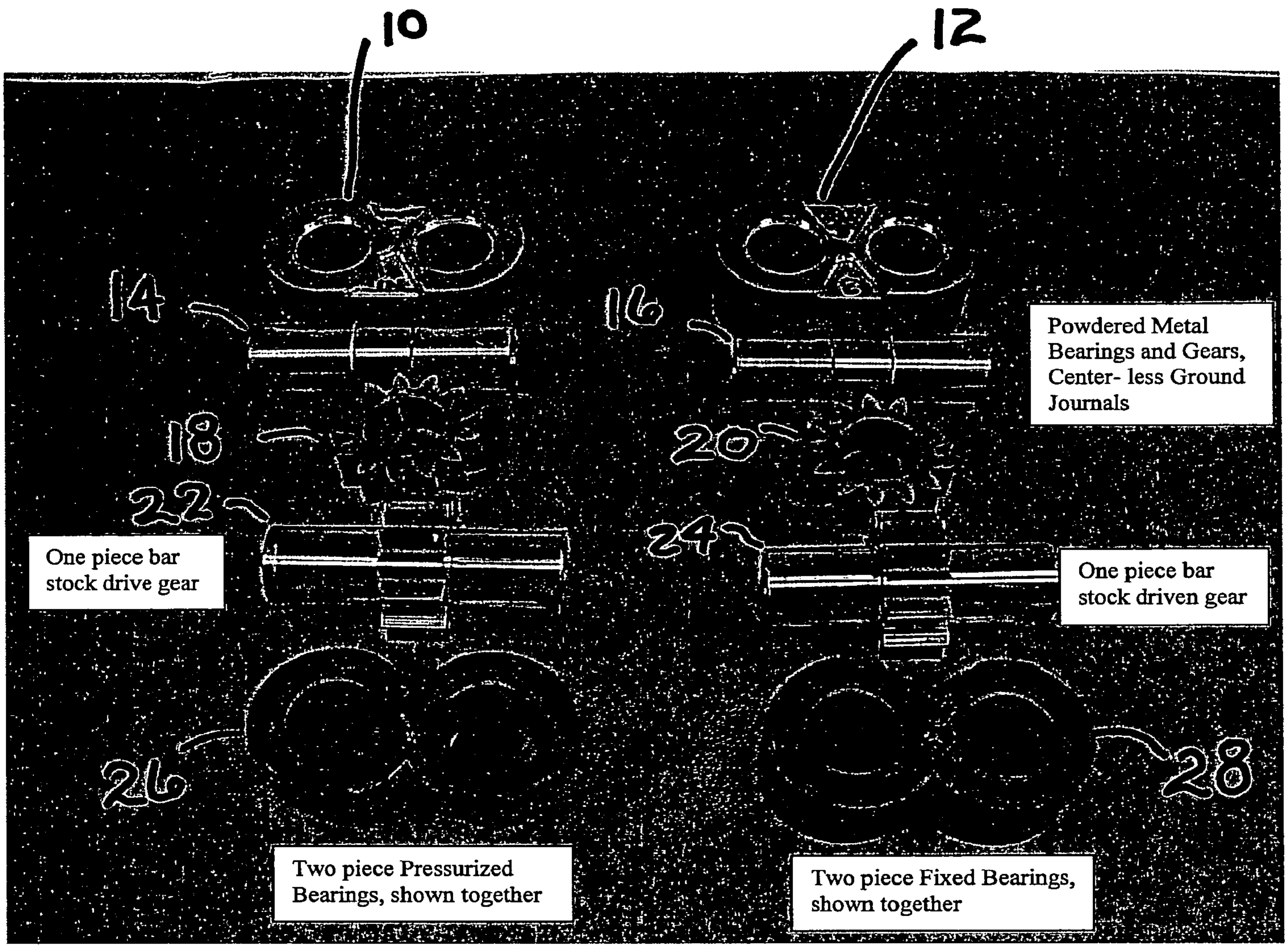
[0021] The singe-piece design of components 10, 12 also allows for greater control of the two holes in centerline-to-centerline positioning. Where the control may be as much as plus or minus one hundredth millimeter, whereas using the two-piece design, or the figure-eight design, it would need to be machine leveled to obtain that exactness, which would be very time consuming. Additional difference between the two-piece design 26, 28 and the single-piece design 10, 12 is that, as can be noted, since they are separate portion connected at a center portion it is possible that separation of the two pieces may occur thereby not allowing functional operation. On the other hand, in a single-piece design, they will not be able to separate.

[0022] Being net shaped formed the present powder metal bearings of FIGURES 1 and 2-4, is that they do not require secondary machining. Particularly, using powdered metal technology, it is desirable not to undertake machining, as it simply adds on the cost, and a benefit of powdered metal technology is that it is formed without the requirement of extensive machining. Rather, there would simply be some smoothing of the face, but no secondary machining required.

[0023] With continuing attention to FIGURES 2-4, illustrated are various views of two powdered metal bearings in accordance with the present application. Particularly, FIGURE 2 shows top views of the bearings. FIGURE 3 shows a bottom view, and FIGURE 4 shows side views. It is to be understood that the bearings are of different shapes.

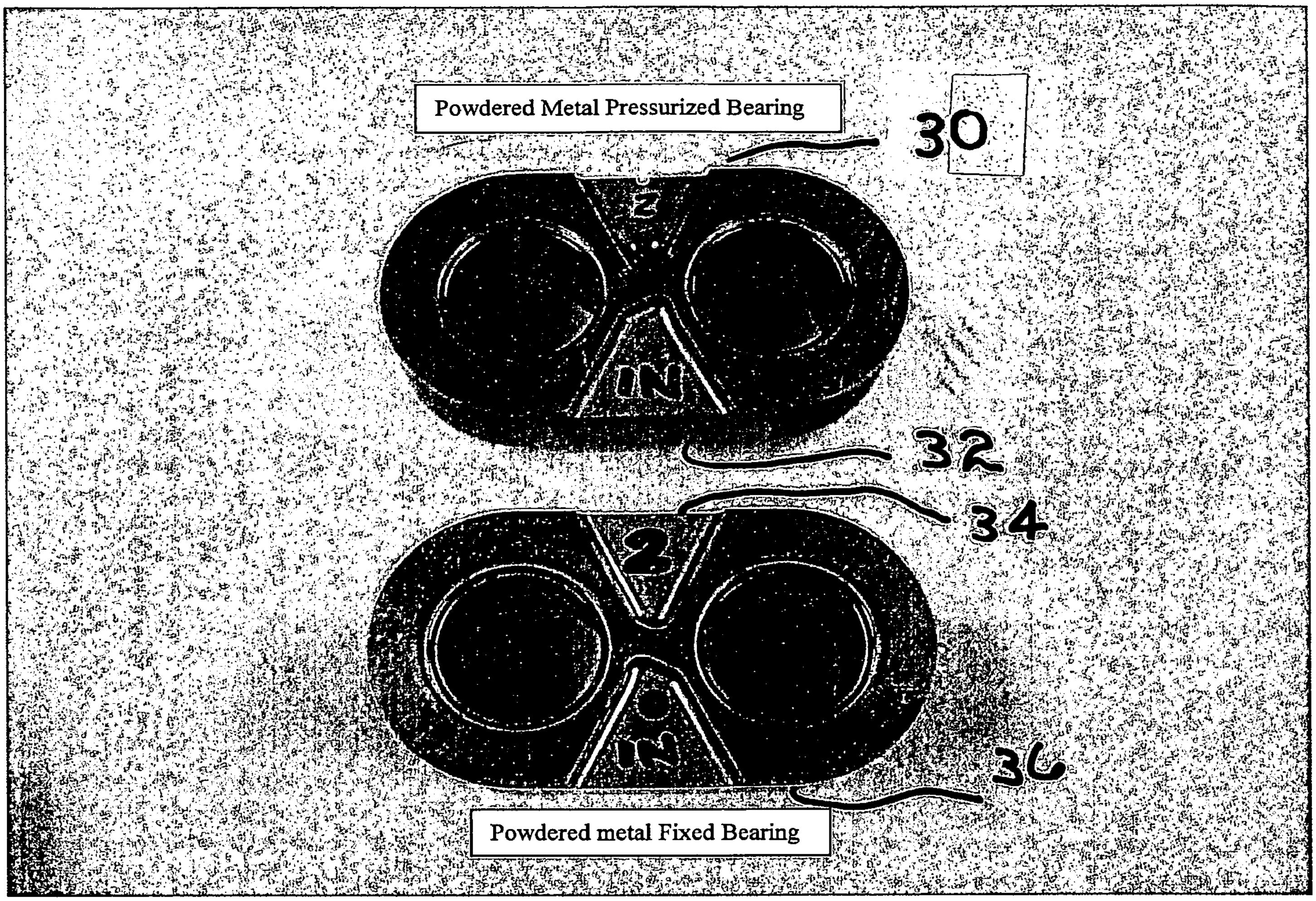
[0024] FIGURE 5 depicts a gear 38 manufactured using powdered metal technology, for use in an airplane fuel pump.

[0025] The exemplary embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.



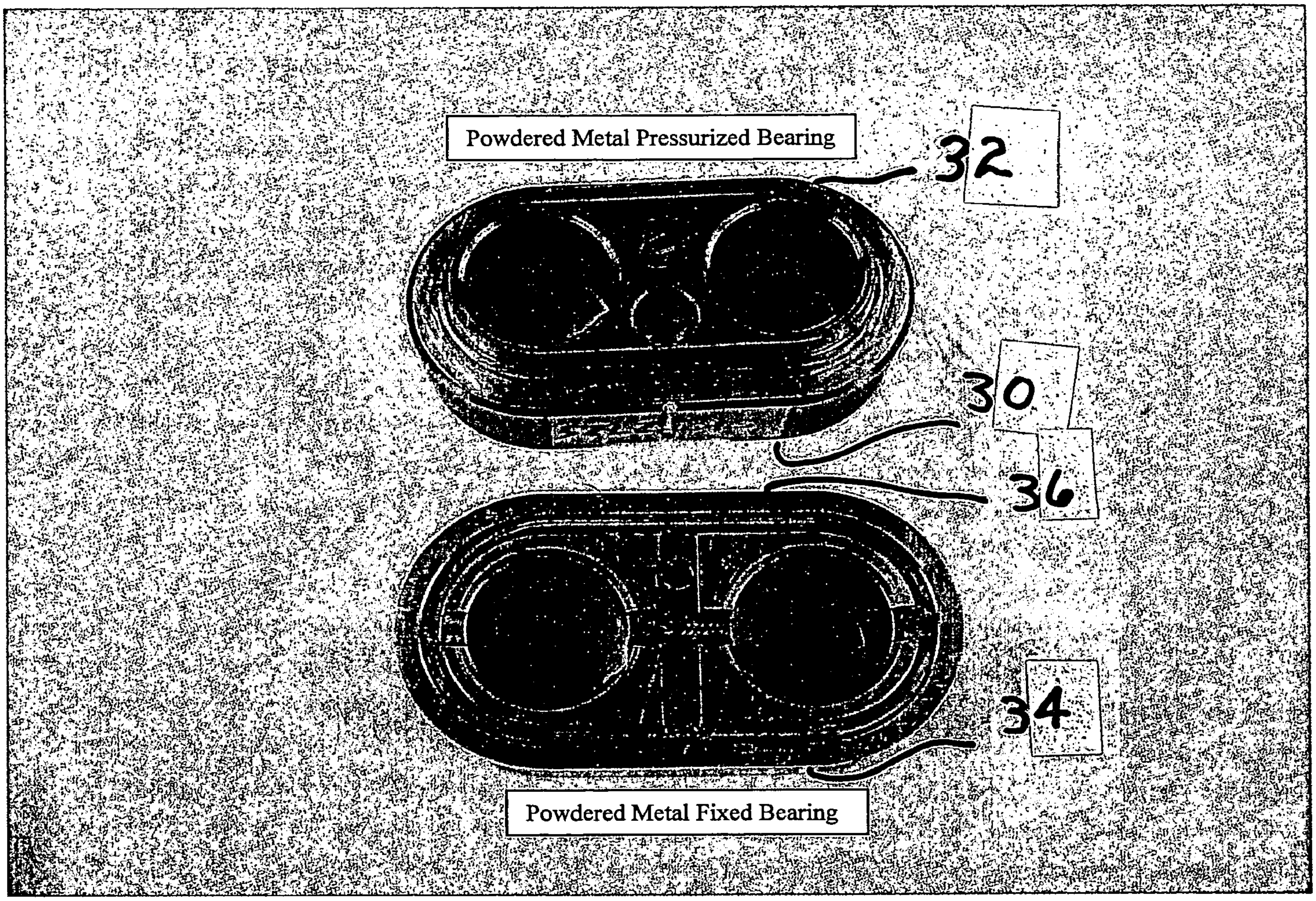
Top portion--- Low Cost Gear Pump Design
Bottom Portion--- Conventional Gear Pump Design

FIGURE 1



Powdered metal Bearings, Top View

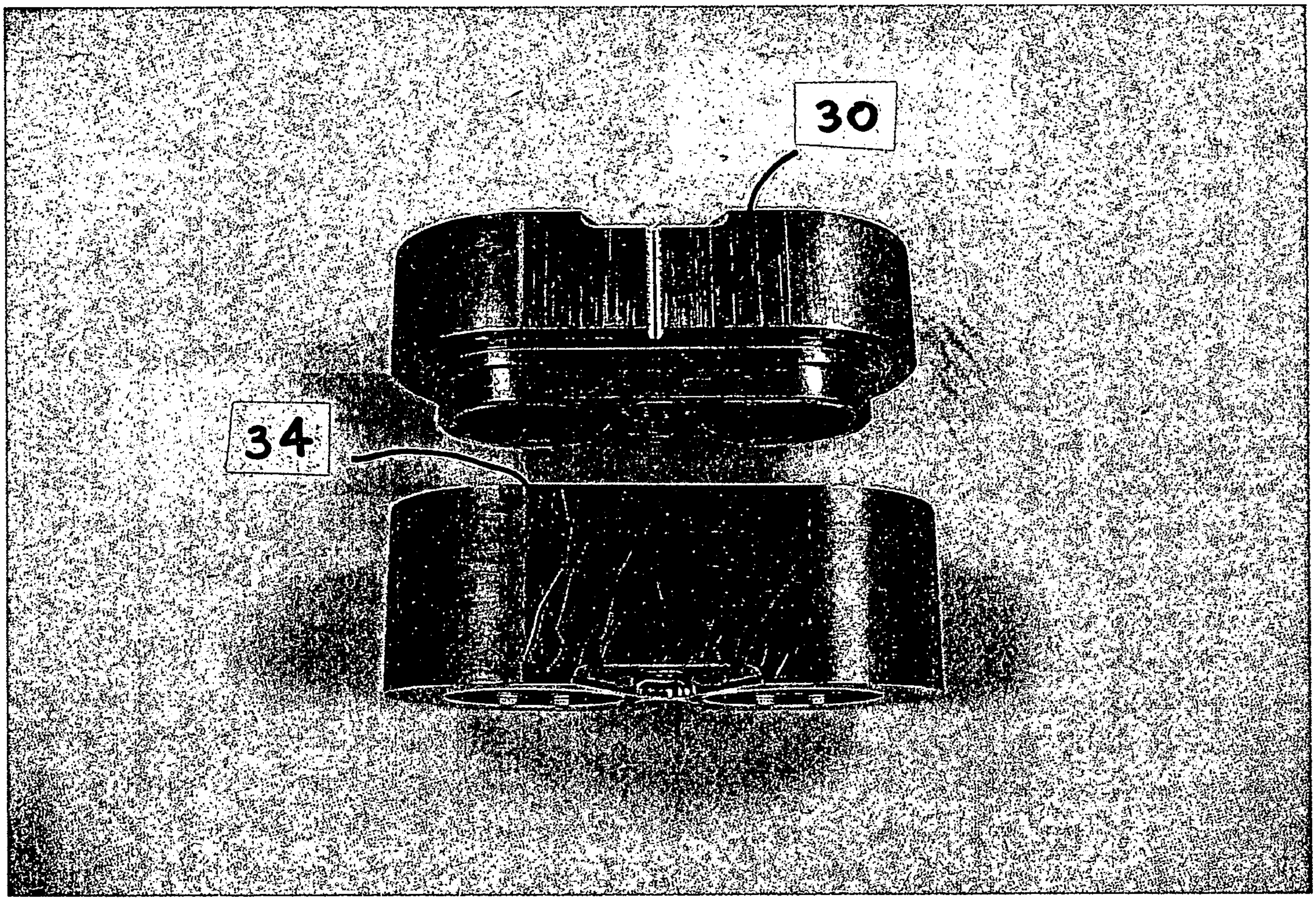
FIGURE 2



Powdered Metal Bearings, Bottom View

Powdered Metal Gear (two per pump)

FIGURE 3



Powdered Metal Bearings, Side View

FIGURE 4

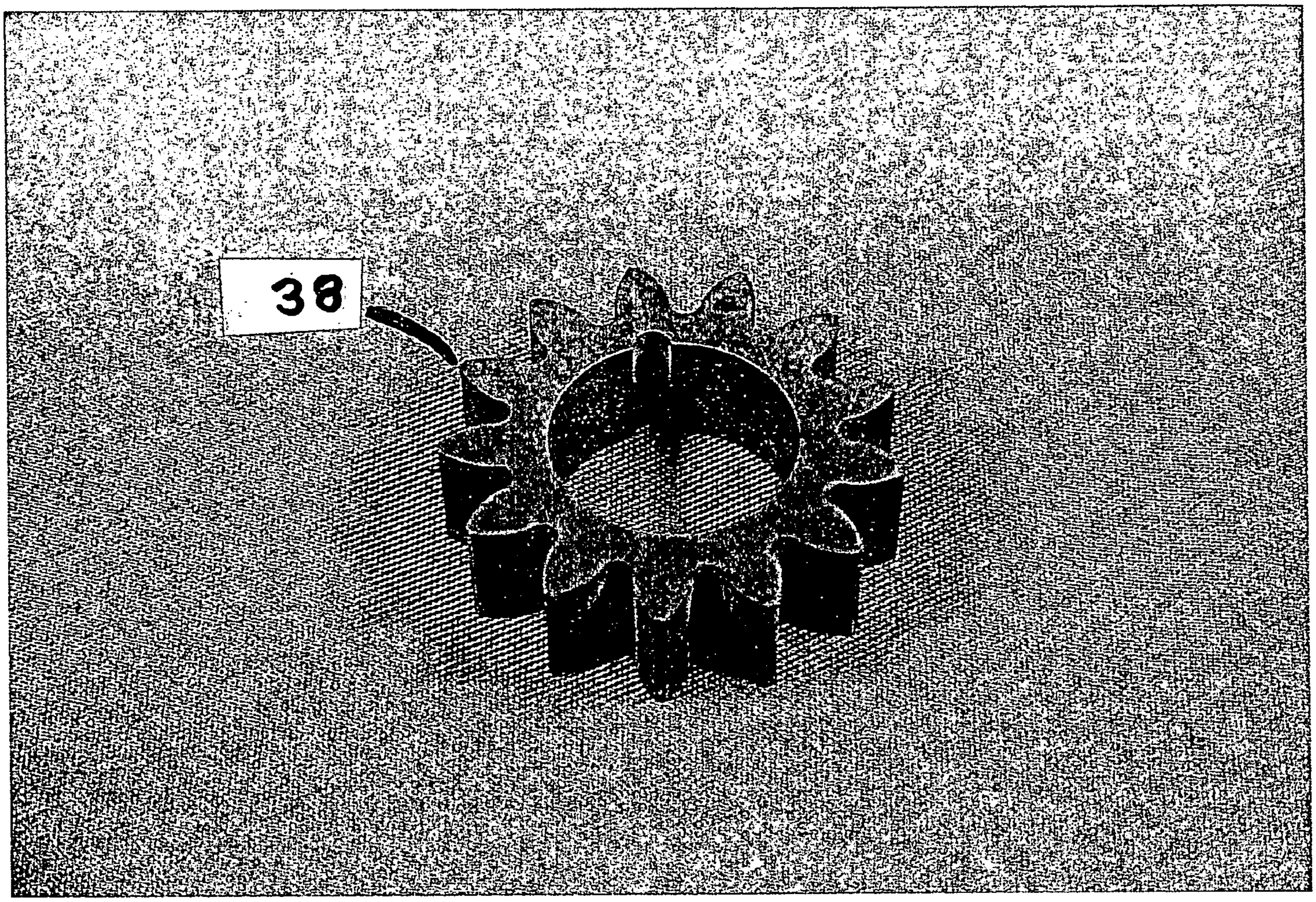


FIGURE 5